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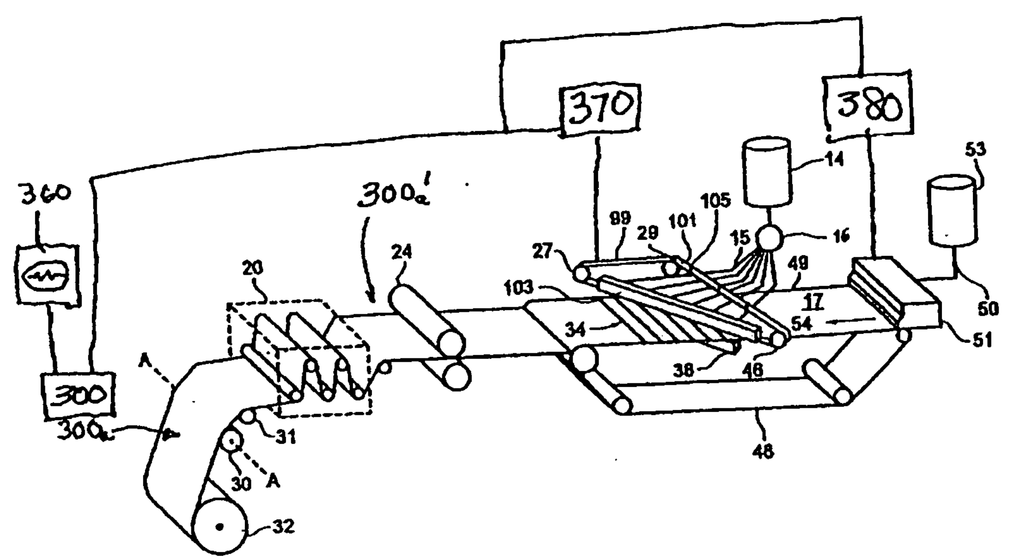
(54) **Title:** THERMOGRAPHIC INSPECTION SYSTEM



(57) **Abstract:** A thermographic inspection station (300) comprises a source of radiation adjacent a web (17) at or about a measurement location (300a), a sensor at a location along the web (17) downstream of the radiation source, and a controller in operative communication with the sensor and the radiation source so that the output signal of the sensor is received and processed by the controller. The source and the sensor can be operative across an entire transverse portion of the web (17) as it passes through the measurement location (300a). The web (17) can be cigarette paper having banded regions thereon.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

THERMOGRAPHIC INSPECTION SYSTEM

Field of the Invention

The present invention relates generally to an optical inspection system for determining the characteristics of a moving web. More specifically, the invention relates to an optical inspection system using transient thermography to rapidly characterize the heterogeneity of a moving web of cigarette paper containing bands.

Background of the Invention

Permeability, density, thickness, and basis weight are important characteristics of cigarette paper. Of particular interest, for example, is the desire to control the permeability in papers designed to reduce the fabric ignition propensity of cigarettes. As explained in commonly assigned U.S. Patent Nos. 5,263,999; 5,417,228; 5,474,095; 5,534,114 and 5,997,691, this can be achieved by creating bands of low permeability to modify the smoldering behavior. The successful design and manufacturing of these papers, therefore, relies on the ability to monitor and control the level and distribution of the various constituents. Commonly assigned U.S. Patent Nos. 5,966,218; 6,020,969 and 6,198,537 disclose techniques for inspecting banded cigarette paper.

Commonly assigned U.S. Patent Nos. 5,417,228 and 5,474,095 disclose cigarette paper comprising a base web and banded regions of add-on material. As illustrated in FIG. 1, an exemplary cigarette 7 might contain two bands 5 of material formed by depositing a layer of cellulosic pulp of increased basis weight on base cigarette paper 3. Cellulon, microcrystalline cellulose, flax or wood pulp,

or amylopectin are some of the various preferred substances which can be used to form the bands.

Commonly assigned U.S. Patent No. 5,534,114 discloses that bands of add-on material can be formed by modifying a conventional Fourdrinier paper making machine to deposit additional layers of cellulose at some stage in the production of the cigarette base paper 3. To streamline the process, the bands are preferably applied while the paper is moving at high speeds, such as 500 feet per minute. At these high speeds, breakdowns and other factors (such as clogged band applicators) can result in the production of a base web having misplaced bands. For example, common anomalies arise when the width of a band deviates from a desired width, or the band becomes skewed so that it is no longer orthogonal with respect to the edge of the paper. Other anomalies arise when the separation between two bands deviates from a desired separation width (also called 'band spacing" herein). Moreover, an irregular band applicator may produce a band with gaps or a band having a contrast which is either too high or too low.

Web inspection devices have been proposed for use in the manufacture of fabrics, film, paper and like material. See, for example, commonly assigned U.S. Patent No. 6,013,915. Some of these devices include a light source for projecting electromagnetic radiation on a moving web of material. The light impinges on the surface of the moving web, where it is reflected and received at a detector device. Any anomalies in the moving web can be detected by investigating the nature of the reflected radiation. For instance, a tear, pinhole or blemish in the web will manifest itself in a spike in the signal level from the detector (which is attributed to an increase or decrease in reflected radiation). This spike can be viewed by connecting the detector output to an oscilloscope, as exemplified by U.S. Patent No. 5,426,509 to Peplinkski.

While techniques utilizing light sources have been proposed for inspecting moving paper webs, such techniques do not rely on thermal transients in the web material to characterize aspects of the manufacturing process. It would be

desirable if real-time monitoring of paper web manufacturing could be achieved by inducing thermal transients in the web to inspect heterogeneity of the web during manufacture thereof.

Summary of the Invention

The present invention provides a method of inspecting an attribute of a web, comprising the steps of moving a web along a path; at a first location along said path, heating across a portion of said web; at a second location along said path spaced from said first location, sensing a thermal characteristic across a portion of said web and generating a signal indicative of said thermal characteristic; and processing said signal in accordance with a known relationship between said signal and said attribute so as to generate an output indicative of said web attribute. The web preferably comprises a cigarette paper and more preferably a banded cigarette paper.

According to a preferred method, the inspected attribute is a basis weight. The heating can be performed using heat lamps, lasers, microwaves, and/or electromagnetic induction or other suitable means and is preferably performed using a broad band pulsed excitation source. According to a preferred method of the invention, the heating progresses almost instantaneously throughout the thickness of the web and the sensing is performed using an infrared camera equipped with a suitable detector such as an indium/antimony based detector. According to a preferred method, the heating and the sensing are both operative across an entire transverse portion of the web.

The present invention also provides an apparatus for inspecting an attribute of a web, comprising a means for moving a web along a path; a means operative to heat across a portion of said web at a first location along said path; a sensor operative to generate a signal responsive to a thermal characteristic across a portion of said web at a second location along said path spaced from said first location; and a processor operative to process said signal in accordance with a

known relationship between said signal and an attribute of said web so as to generate an output indicative of said web attribute. The web preferably comprises a cigarette paper, and more preferably a banded cigarette paper.

According to a preferred embodiment, the attribute is a basis weight and the heating means comprises a broad band pulsed excitation source. According to a preferred embodiment, the heating means comprises heat lamps, lasers, microwaves, and/or electromagnetic induction means. The heating means preferably produces heating almost instantaneously throughout the thickness of the web. The sensing means is preferably an infrared camera using a suitable detector such as an indium/antimony based detector. According to a preferred embodiment, the heating means and the sensing means are both operative across an entire transverse portion of the web.

Brief Description of the Drawings

FIG. 1 (prior art) illustrates an exemplary cigarette comprising a base web and banded regions of add-on material.

FIG. 2 depicts an exemplary machine for producing a web of fibrous material.

FIG. 3 shows an thermographic inspection system according to the instant invention.

FIG. 4 illustrates the inspection geometry.

FIG. 5 illustrates the reduction in contrast as a sample approaches equilibrium.

FIG. 6 shows transposition of the morphological features associated with inspection of opposite sides of a sample.

FIG. 7 shows the time dependence of thermal decay for different basis weights.

FIG. 8 illustrates the decay of the coefficient of variance statistic within the region of interest.

FIG. 9 shows the dependence of thermal response on bulk basis weight.

FIG. 10 illustrates the sensitivity of the technique

FIG. 11 shows SEM micrographs contrasting the morphology of the base paper with that of the band.

FIG. 12 is a thermal image of a banded paper specimen taken 33 ms after a heating pulse.

Detailed Description of the Preferred Embodiments

In the following description, for purposes of explanation and not limitation, specific details are set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the present invention can be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods, devices, and circuits are omitted so as not to obscure the description of the present invention with unnecessary detail.

Typical cigarette papers exhibit detectable spatial variations of effective bulk properties. These variations may arise from fiber size distribution, fiber orientation, additives, and detailed microstructure. Paper heterogeneity is typically manifested as a variation in local heat transport within the paper.

Analysis of a paper's response to thermal transients provides a basis for the investigation of paper design and variations inherent in the paper manufacturing process. Methods capable of rapidly and nondestructively assessing these variations may provide significant benefits in the development and manufacturing of paper products.

Transient thermography is a technique that can afford rapid, on-line, real-time monitoring of paper manufacturing processes. Transient thermography advantageously provides full field data and, significantly, is non-obtrusive; it does not require direct contact with the paper material. Furthermore, the technique requires only minimal heating of the paper and has a high spatial resolution.

Thermographic techniques are typically divided into two categories: passive and active. Passive thermography is an essentially qualitative technique that relies on the detection of existing thermal gradients generated during typical processing or operating states, for example, heat leakage from buildings, heat generated from friction or other mechanical processes, reaction processes, and ohmic heating. Active thermography, in contrast, is based on the generation and monitoring of thermal gradients in structures by inducing heating and/or cooling and can therefore be tailored to optimize the desired material property characterization. Excitation may be temporally and/or spatially modulated. For example, because the cigarette paper to be inspected according to the invention effectively integrates the heat input per unit area, the local temperature rise has a minimal dependence on heat transport through microstructure. It is possible to access microstructural information, however, by monitoring the in-plane heat transfer, which can be done by spatially modulating the pulsed excitation. Compared with passive thermography, active thermography produces an enhanced differentiation of structural features by inducing thermal gradients using, for example, heat sources such as heat lamps, lasers, microwaves, and electromagnetic induction. Alternatively, thermal gradients can be induced in an already heated object using, for example, convective cooling, quenching with liquid nitrogen, and parasitic conduction. The choice of excitation mode is driven by the material characteristics of the sample. For example, microwaves can be used to heat incipient water within a sample. Care must be taken not to exceed temperature thresholds that may damage the host material.

The essence of quantitative thermography is assessing the interaction between temperature fields and the structure of interest. The mathematical formalism for the conduction of heat in solids provides the theoretical basis for understanding these interactions. When the material of interest is opaque, the analytical solution to the equation of continuity for heat conduction in a stationary solid can be used in conjunction with the time resolved thermal data to gain insight

into subsurface features of the structure. In the case of cigarette papers, significant transmission of the excitation energy occurs. Because the absolute temperature excursions are small, radiant losses have a second order effect. For observation times long relative to the excitation pulse of 10 μs and short relative to the period over which convective and conductive losses occur, a first approximation of the resulting temperature, at ΔT, rise is given by equation 1.

$$\Delta T = \frac{Q(\lambda)}{\rho C_v} \qquad (1)$$

$Q(\lambda)$ is the absorbed energy, which will generally have a spectral dependence. C_v, is the specific, heat per unit volume, and ρ is the density. The period over which this adiabatic assumption is valid depends on the boundary conditions of the heat transfer problem and the material properties.

Successful application of transient thermography relies first on the ability to access and monitor relevant thermal information, and second on the ability to infer from this information details of morphology and formation mechanisms. The development of highly sensitive focal plane array detectors and read-out architecture has increased infrared imaging speeds. In addition, advances in computing speed and reduced circuit size have combined to provide the power necessary to perform the near real time data processing necessary for quantitative materials evaluation.

The method according to the invention utilizes a broad band pulsed excitation source to initiate low-level thermal gradients within the paper. The resulting heat flow is then monitored using a high-speed, high sensitivity infrared camera. The detailed behavior of the transient temperature field depends on the boundary conditions and the local values of specific heat, thermal conductivity, and density. Cigarette papers typically exhibit subtle spatial variations of these bulk properties. These variations may arise from fiber size distribution, fiber orientation, additives, thickness, and moisture content combining to yield a unique

microstructure. Analysis of these associated thermal transients provides a basis for the investigation of paper design and variations inherent in the paper manufacturing process.

According to exemplary aspects, the inspection system of the present invention is designed to inspect the characteristics of cigarette paper during its manufacture. Thus, before discussing the inspection station itself, it is useful to first describe exemplary aspects of a cigarette paper manufacturing system.

FIG. 2 illustrates an exemplary machine for producing a web 17 of fibrous material. As shown there, a central tank 53 of refined pulp (such as refined flax or wood pulp) is delivered to a head box 51 by means of a plurality of conduits 50. The Fourdrinier wire 49 transports the slurry pulp from the head box 51 in the direction of the arrow 54. At this point, the pulp has a high moisture content. Water is allowed to drain from the slurry, and optionally is also removed by vacuums (not shown). The return loop 48 of the Fourdrinier wire 49 is also shown.

The band application assembly 99 is located downstream of the headbox 51. Assembly 99 generally includes a frame housing an endless perforated steel belt 105, which is guided by drive wheel 27, guide wheel 29, and follower wheel 46. The belt 105 consists of orifices 101, which may be of equal or varying size, and which may be equally or variably spaced. The bottom of the assembly 99 includes a chamber box 103 containing a reservoir of slurry supplied from tank 14 via conduits 15. The flow of slurry through conduits 15 is maintained at appropriate levels by a flow distribution system comprising a series of pumps in conjunction with a pressure monitoring system 16.

Slurry is dispensed through the perforations 101 in the endless steel belt 105 as it passes through the bottom portion of the chamber box. The belt is moving as the slurry is dispensed, thereby compensating for the motion of the web moving beneath the chamber box. According to exemplary embodiments, the belt is moved at a rate of 1000 feet per minute to compensate for a Fourdrinier wire

moving at a rate of 500 feet per minute. As a result of this compensation, the chamber box applies the bands 34 so that they are orthogonal to the edges of the web 17. If the bands are not completely orthogonal, the angle of the band application assembly 99 can be adjusted. Alternatively, a non-orthogonal application of bands may be desired. The band application assembly 99 is preferably situated obliquely across the Fourdrinier wire 49 at a location where the condition of the web 17 is such that it can accept the add-on material without the add-on material dispersing itself too thinly throughout the local mass of the base web slurry. Preferably, a vacuum box 38 is located coextensively beneath the chamber box 103 of the band application assembly 99 so as to provide local support for the Fourdrinier wire 49 and facilitate the bonding/integration of the add-on slurry with the base web 17. The vacuum box 19 is operated at a relatively modest vacuum level, such as about 60 inches of water or less. Further details regarding the band application assembly 99 are disclosed in commonly assigned U.S. Patent No. 5,534,114, the entire disclosure of which is incorporated herein by reference.

The banded paper then passes through one or more press rollers 24 which squeeze as much water out of the paper as possible through mechanical pressure. The remaining water can then be evaporated out of the paper by passing the paper over the surface of one or more drying rollers 20. These moisture removal techniques are conventional in the art. Furthermore, those skilled in the art will appreciate that other moisture-removal techniques can be used to replace or supplement the above-identified techniques, such as the conventional use of a felt web to remove moisture from the paper.

According to exemplary aspects of the present invention, the inspection station of the present invention is positioned downstream from the drying rolls 20, just before the paper is wound on the final paper reel 32. More specifically, in the exemplary embodiment shown in FIG. 2, the inspection station is positioned over the roller 30, which follows roller 31, at a position denoted by the line A-A.

Roller 30 can be a stationary stainless steel tube having a diameter of six inches. Those having skill in the art will recognize that the inspection station can be placed at a variety of locations downstream of the band application assembly 99, or more than one inspection station can be employed to inspect the paper web. Thus, an exemplary thermographic inspection station 300 is operative upon the web 17 at a location 300a preferably downstream of the drying rolls 20 or in the alternative, at another location 300a' along the web 17, upstream of the drying rolls 20.

Referring to FIGS. 2-3, the thermographic inspection station 300 preferably comprises a source of radiation 310 adjacent the web 17 at or about the location 300a, a sensor 320 at a location along the web 17 downstream of the source 310 and a controller 330 in operative communication with the sensor 320 and the source 310 so that the output signal of the sensor 320 is received and processed by the controller 330. Preferably, the source 310 and the sensor 320 are constructed in accordance with the above teachings and preferably are both operative across an entire transverse portion of the web 17 as it passes through the location 300a.

Preferably, the controller 330 is programmed or otherwise arranged to include a look-up table 340 or other form of database or algorithm embodying a relationship of a signal obtained from the sensor 320 to a basis weight of the web 17 or other selected attribute of the web 17. For example, the controller 330 could reference a look-up table 340 embodying the relationship of sensor signal to changes in web basis weight for a given time (t) such as shown in Fig. 9.

Preferably the output of the controller 350 is communicated to a monitor 360 and/or control units 370 and 380. Control unit 370 is programmed or otherwise arranged to adjust operation of the band application assembly 99 responsively to the measure of basis weight at banded regions of the web 17 by the inspection station 300, while control unit 380 is programmed or otherwise arranged to control production of the web 17 of fibrous material. Thermographic

inspection station control unit 330, band application assembly control unit 370, and web production control unit 380 can be operated synergistically to monitor, characterize, and control the heterogeneity of a moving web of cigarette paper containing bands according to the present invention.

Advantageously, the thermal output of the source 310 is to be selected such that the heat progresses almost instantaneously throughout the depth (thickness) of the web, such that the transient thermal effect produced by the source 310 manifests essentially along the plane of the web 17 as the web progresses toward the sensor 320, with only minimal or essentially no confounding effects from variants attributable to the web thickness.

EXAMPLE

Paper specimens were cut into rectangular samples measuring approximately 30 mm by 50 mm, and were then suspended in an aluminum frame that contacted the samples along their edge. The frame was capable of holding six samples. The surface of the frame was coated with a flat black paint that approximated a black body spectral response. Thus, the frame surface adjacent to the specimens provided a reference to assess the uniformity of the excitation field and the camera response.

The technique utilized a broad band pulsed excitation generated by two Balcar® flash lamps. The lamps provided a heat pulse lasting approximately 10 μs. Peak surface temperatures were estimated to be less than 30°C above ambient with no indication of permanent changes in the paper. The resulting low level thermal gradients within the paper were monitored using a Raytheon Radiance HS® infrared camera situated on the same side of the specimens as the paper. FIG. 4 illustrates the inspection geometry showing the specimen holder surface 400 normal to the optical axis of the camera 410, a pair of flash lamps 420, and a data acquisition and synchronization unit 430.

The Radiance HS® camera contains a 256 x 256 indium/antimony (InSb) focal plane array and has the capability of detecting equivalent black body temperature differentials as low as 0.025 mK. A 25 mm lens was used in combination with a camera-to-sample distance which provided a field of view approximately 10 cm x 10 cm. This arrangement was chosen so that the full width of the specimen holder was in the field of view of the camera. InSb detector technology was chosen for several reasons. First, in comparison with more popular and less expensive platinum/silicon (PtSi) focal plane array cameras that have a quantum efficiency of less than 10%, the InSb detector has a high quantum efficiency, greater then 85%. Second, the readout electronics of the InSb camera provided "snap shot" data acquisition. This capability allows all 66,536 CCD detectors to be integrated over the same time period. The combination of high efficiency, simultaneous detector integration, and 12-bit digital output provided the required spatial resolution and fast response required. Samples were typically inspected using a 120 Hz frame rate.

A preliminary set of specimens was used to configure the instrumentation and identify the sensitivity of the technique to detect subtle features in cigarette paper. The thermal diffusivity for the paper samples was not available. The thermal diffusion time was estimated, however, a using a typical thermal diffusivity of 0.003 cm^2/s from other cellulose fiber materials. Using a typical paper thickness of 0.045 mm yields a thermal transient time on the order of 1 ms. Thermal gradients normal to the surface of the paper diffuse very rapidly and are not expected to be observed using the current technique.

FIG. 5(a) is an image of a specimen obtained 33 ms after the excitation pulse. The gray scale level is indicative of the relative surface temperature of the paper. The unique mass distribution is clearly indicated by the differential heating of the sample. FIG. 5(b) is the same specimen 492 ms after the flash. It is clear that much of the morphological details have been lost. In addition, heat loss to the specimen frame is indicated by the steep gradient along the edge of the specimen.

Even though the sample temperature is above ambient several seconds after the flash, little detail remains. This suggests that the observed details are not surface dependent but an indication of the material distribution within the volume of the paper.

To investigate the influence of the paper surface, the same specimen was imaged on the opposite side. FIGS. 6(a) and 6(b) compare the result. Note that the morphological features transpose indicating that the observed heterogeneity is present within the volume of the sample. The sample was rotated about the x-axis.

A second group of specimens was used to quantitatively characterize papers wherein the permeability was modified by varying the addition of calcium carbonate ($CaCO_3$) and fiber refinement. The manufacturing data for these materials are shown in Table 1. The characterization of a homogeneous paper design provided a basis for interpreting results obtained for banded paper.

Table 1 sets forth data regarding cigarette papers with range of permeability and basis weight. The variation in the weight is indicated as the upper and lower control limit of the process. The variation in the permeability is indicated as the standard deviation of samples taken within the region of the evaluated specimens.

Table 1

Paper Code	200	354	362
Basis wt. (g/m$^{2)}$	26.0 $\pm$ 0.2	26.5 $\pm$ 0.2	27.0 $\pm$0.2
Permeability (CU)	64 $\pm$ 9.5	83 $\pm$ 5.9	91 $\pm$ 10.9

To insure a common time base and excitation flux, the three papers were heated simultaneously. Analysis of the thermal responses was achieved by defining a rectangular region of interest (ROI) which encompassed approximately 80% of the sample surface. FIG. 7 illustrates the average thermal decay within an ROI. Although the statistical capability of the method was not rigorously

evaluated, the rank order of the curves is consistent with that expected from equation 1. The lowest basis weight paper exhibited the highest initial temperature while the highest mass sample exhibited the least heating. The spatially averaged signal reflects the average basis weight of a particular sample type and reinforces the interpretation that the detailed inter-sample morphology is due to local mass variation. FIG. 8 illustrates the decay of the coefficient of variance (COV) statistic within the ROI. The COV is one measure of the contrast within the image and provides a quantified result of the loss of detail illustrated by FIG. 5(b). Physically, the decay of the COV reflects in-plane heat transfer within the paper. The equilibration of different density regions reduces the variation in the image.

FIG. 9 shows the dependence of thermal response on bulk basis weight. It is clear, with reference to Table 1, that basis weight is correlated with permeability. The increase in mass results in a higher heat capacity and a lower temperature. FIG. 10 illustrates the sensitivity of the technique and is derived from extracting the slope from FIG. 9 at each time. The sensitivity is greatest at early times.

While optical reflectance techniques have been developed to rapidly measure the dimensions of the band within the plane of the base paper, a rapid means of assessing the uniformity of mass distribution and permeability is preferably combined therewith to carry out real time inspection of the banded paper. The bands are formed by depositing highly refined flax fibers on the surface of standard cigarette paper while the base paper is still wet. This allows sufficient mobility of the band fibers to migrate into the base paper. The result is a combination of mechanical and hydrogen bonding of the two layers into a single structure. The final paper may have fairly high permeability associated with the base material (e.g. 45 CU) and a much lower permeability (e.g. 10 CU) in the banded area.

The microstructure of any material has a significant impact on transport properties such as permeability and heat transfer. FIG. 11 shows SEM micrographs contrasting the morphology of the base paper with that of the band. FIG. 11(a) is a cross sectional view. The enhanced density of the band is clearly seen on the left. FIG. 11(b) is a top view. The lower density associated with the longer fiber lengths of the base paper (right) are easily distinguishable from the denser band. Both FIGS. 11(a) and 11(b) illustrate the increased density associated with the highly refined fibers in the band.

FIG. 12 is a thermal image of a banded paper specimen taken 33 ms after a heating pulse. The distribution of band mass is clearly visible as a dark rectangle at the bottom of the image. In addition, the continuity in the morphology of the base paper is also illustrated. Thus, the image provides a map of the mass distribution within the specimen. Note that while this mass influence is consistent with the results illustrated in FIG. 9, the result is contrary to that which one would expect by extrapolating the correlation of basis weight with permeability (i.e. a lower permeability yielding a lower signal). The difference can be attributed to the differences in microstructures. The minor variation in base paper basis weight was achieved by varying $CaCO_3$ and possibly fiber distribution. These manufacturing parameters slightly modify the microstructure controlling the airflow paths and permeability. In contrast, the bands were formed using fibers much shorter than the base material. The result is a much denser paper with significantly different microstructures. Thus in the latter case, mass increase is accompanied by a decrease in permeability.

By way of example, the present invention has been described in the context of detecting bands located on cigarette paper. One with ordinary skill in the art will realize, however, that the present invention extends to the detection of any information formed on sheet-like material. For instance, the present invention can be used to detect bands on other papers, including papers prepared for security purposes, such as paper currency, stock certificates, bearer negotiable bonds, etc.

Through the use of pulsed excitation thermography, the invention demonstrates the rapid evaluation of the in-plane mass distribution in cigarette papers. Analysis of the associated thermal response allows for the characterization of the subtle variations inherent in the paper manufacturing process. Within a given set of manufacturing parameters and a general type of microstructure (e.g. base paper or band microstructure) the described heating technique may reflect the distribution of permeability within a specimen.

The above-described exemplary embodiments are intended to be illustrative in all respects, rather than restrictive, of the present invention. Thus, the present invention is capable of many variations in detailed implementation that can be derived from the description contained herein by a person skilled in the art. All such variations and modifications are considered to be within the scope and spirit of the present invention as defined by the following claims.

<u>Claims</u>:

1. A method of inspecting an attribute of a web, comprising the steps of:

moving a web along a path;

at a first location along said path, heating across at least a portion of said web;

at a second location along said path spaced from said first location, sensing a thermal characteristic across at least a portion of said web and generating a signal indicative of said thermal characteristic; and

processing said signal in accordance with a predetermined relationship between said signal and said attribute so as to generate an output indicative of said web attribute.

2. The method of claim 1, wherein said web comprises a cigarette paper.

3. The method of claim 1, wherein said web comprises a banded cigarette paper.

4. The method of claim 2, wherein said attribute is basis weight of the paper.

5. The method of claim 1, wherein said heating is performed using one or more heat lamps, lasers, microwaves, and/or electromagnetic induction.

6. The method of claim 1, wherein said heating is performed using a broad band pulsed excitation source.

7. The method of claim 1, wherein said heating progresses substantially instantaneously throughout the thickness of the web.

8. The method of claim 1, wherein said sensing is performed using an infrared camera.

9. The method of claim 6, wherein said camera includes an InSb based detector.

10. The method of claim 1, wherein the heating and the sensing are both operative across an entire transverse portion of the web.

11. An apparatus for inspecting an attribute of a web, comprising:

a means for moving a web along a path;

at a first location along said path, a means operative to heat across a portion of said web;

at a second location along said path spaced from said first location, a sensor operative to generate a signal responsive to a thermal characteristic across a portion of said web; and

a processor operative to process said signal in accordance with a predetermined relationship between said signal and an attribute of said web so as to generate an output indicative of said web attribute.

12. The apparatus of claim 11, wherein said web comprises a cigarette paper.

13. The apparatus of claim 11, wherein said web comprises a banded cigarette paper.

14. The apparatus of claim 12, wherein said attribute is basis weight of the paper.

15. The apparatus of claim 11, wherein said heating means comprises one or more heat lamps, lasers, microwaves, and/or electromagnetic induction means.

16. The apparatus of claim 11, wherein said heating means is a broad band pulsed excitation source.

17. The apparatus of claim 11, wherein said heating means produces heating substantially instantaneously throughout the thickness of the web.

18. The apparatus of claim 11, wherein said sensing means is an infrared camera.

19. The apparatus of claim 18, wherein said camera includes an InSb based detector.

20. The apparatus of claim 11, wherein the heating means and the sensing means are both operative across an entire transverse portion of the web.

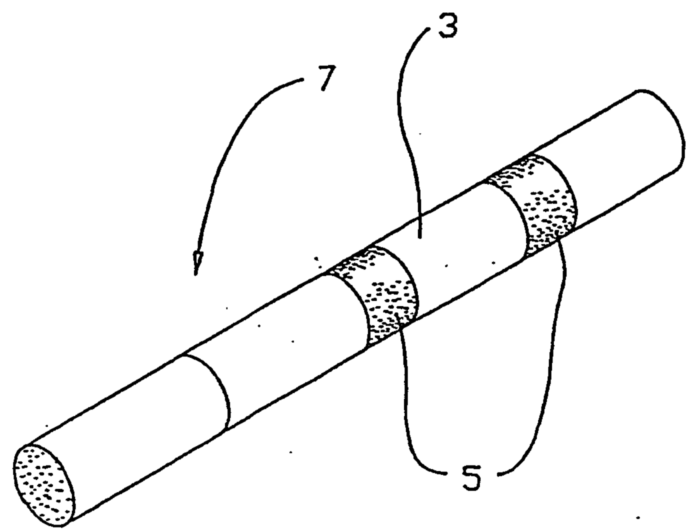
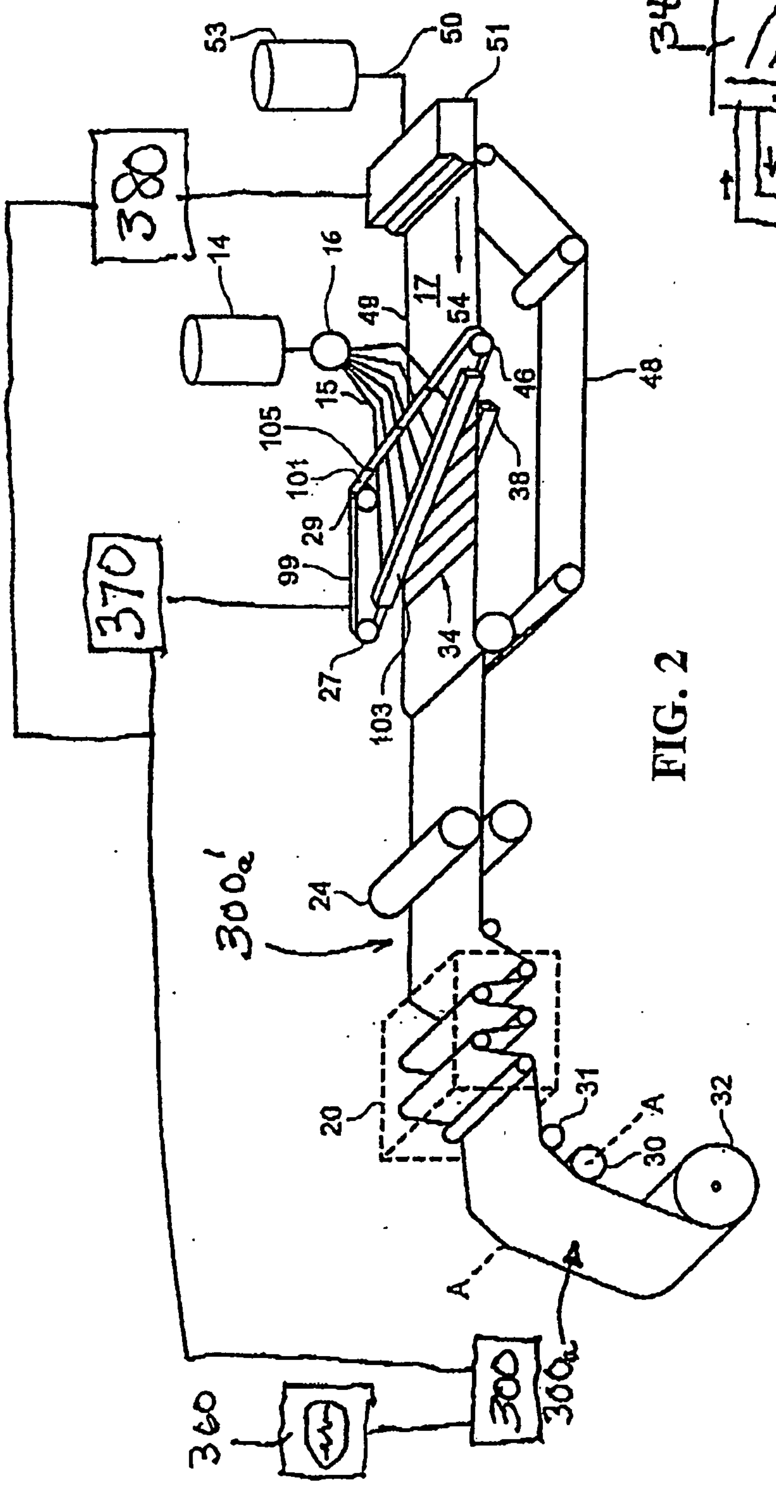


Fig. 1


53
50
51
380
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15
105
101
29
99
370
27
103
34
38
24
300a'
20
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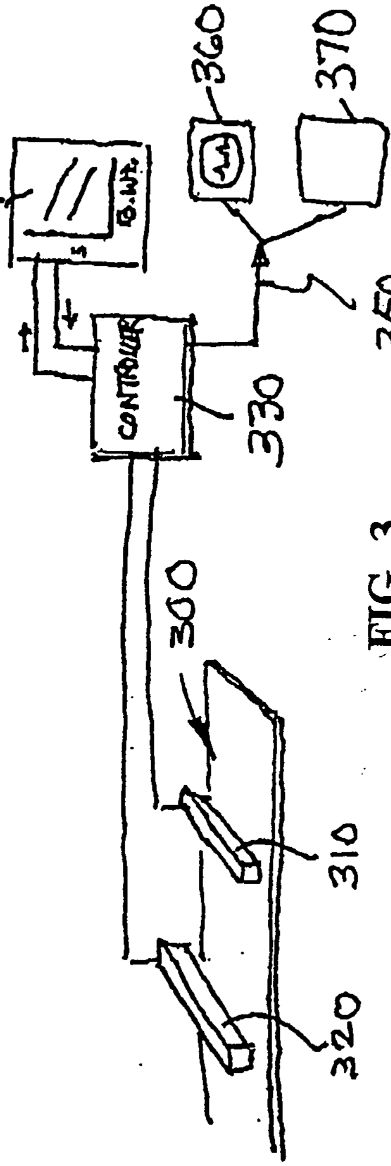
A
32
30
300a
300
360

FIG. 2


340
B.WT.
CONTROLLER
330
350
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370
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310
320

FIG. 3

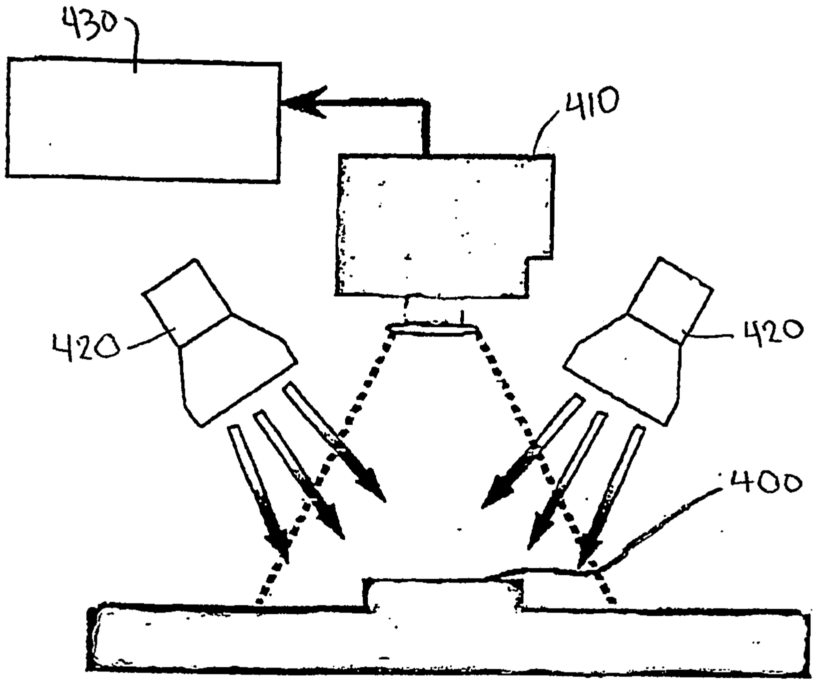

FIG. 4

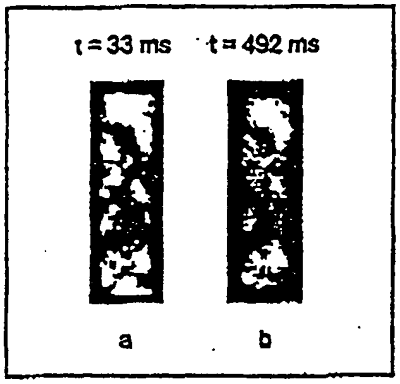

FIG. 5

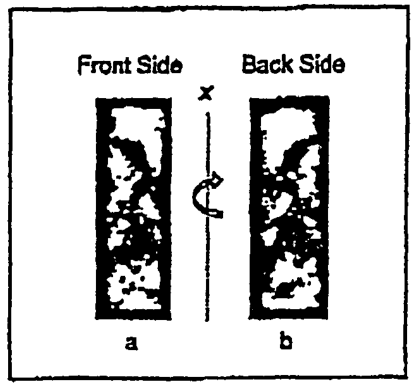

FIG. 6

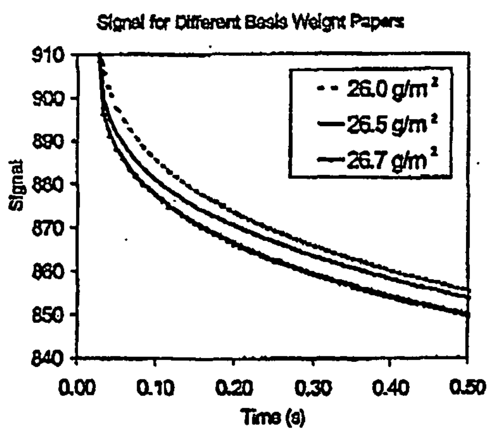

FIG. 7

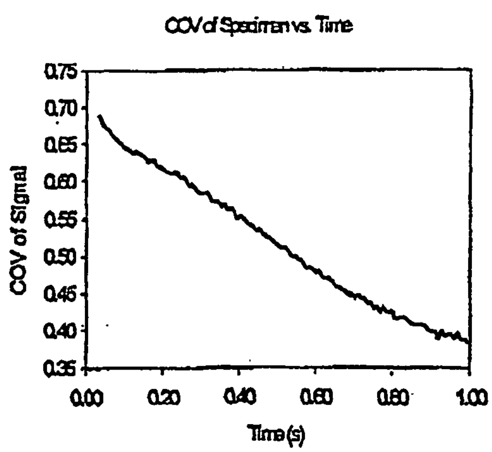

FIG. 8

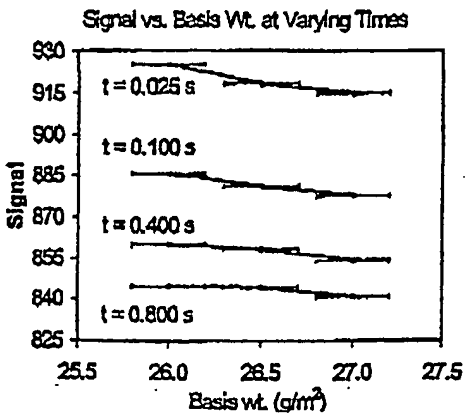

FIG. 9

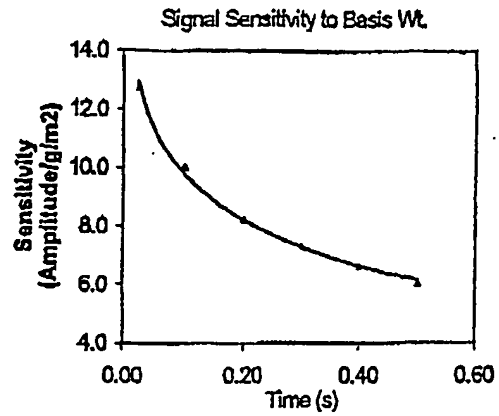

FIG. 10

FIG. 11a

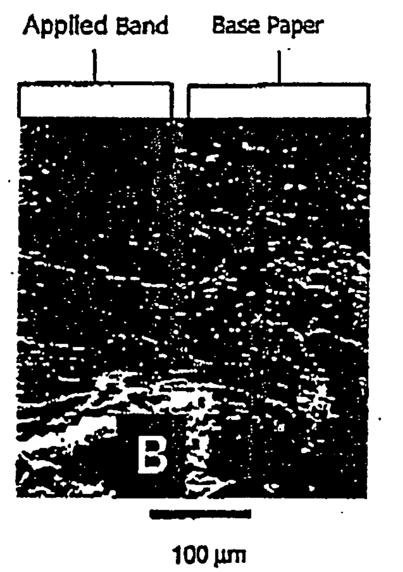

FIG. 11b

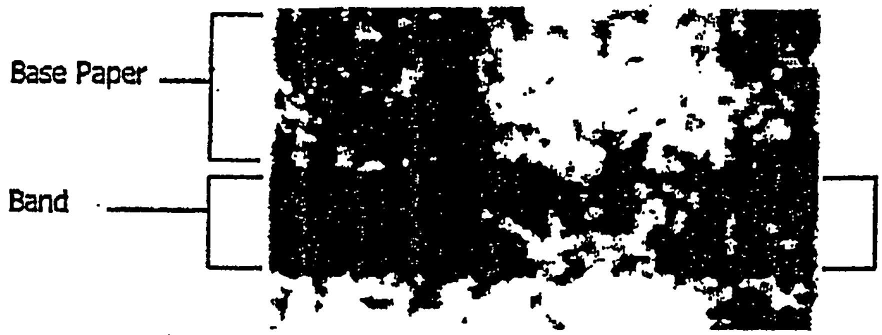

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/32191

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G01N 25/00; G01T 1/16
US CL :250/341.6
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 250/341.6, 347, 349; 374/10, 11, 45

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,062,726 A (FORESTER et al.) 16 May 2000 (16.05.2000), see abstract, Cols. 6-8.	1, 5, 7, 8, 10, 11, 15, 17, 18, 20
Y		2-4, 6, 9, 12-14, 16, 19
X	US 5,823,677 A (FORESTER et al.) 20 October 1998 (20.10.1998), see abstract and Cols.6-8.	1, 5, 7, 8, 10, 11, 15, 17, 18, 20
Y		2-4, 6, 9, 12-14, 16, 19

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 DECEMBER 2001	16 JAN 2002

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/32191

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,792,271 A (SANDBLOM) 12 February 1974 (12.02.1974), see abstract, Col.2, lines 50-68, Cols.3-4.	4, 6, 9, 14, 16, 19
A	US 4,840,706 A (CAMPBELL) 20 June 1989 (20.06.1989), see entire document.	1-20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/32191

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

USPTO WEST 2.0
Search terms: web, paper, cigarette, temperature, heating, infrared, IR, sensor, detector, camera, source, processing, signal, paper weight, lamp, laser